Application Number: 09/683,587
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Marked Up Copy of Amended Paragraphs

MARKED UP COPY OF AMENDED PARAGRAPHS

Legends: {text} signifies a deleted text, text signifies an added text.

Following are marked up copies of amended paragraphs for every amendment listed in the "Specification Amendments" list enclosed in the same communication.

1. Paragraph 13:

[0013] {OTHER PUBLICATIONS} Other Publications

2. Paragraph 18:

[0018] The physiological cues are summarized in {Okoshi"s} Okoshi's book (Okoshi, 1976) and they are: accommodation, convergence, binocular parallax and monocular movement parallax. Accommodation is a cue given by the adjustment of the focal length of the eye's crystalline lens when an eye focuses on a particular object. Convergence is a cue given by the angle made by the two viewing axes of observer's eyes. Binocular parallax is a cue caused by the difference between the views seen by the two eyes of an observer. Monocular movement parallax is a cue observed when a person is moving and is caused by the changing view in each of the person's eyes. Accommodation and monocular parallax are available even when we see an object with a single eye.

3. Paragraph 21:

[0021] {OLE_LINK3} Another stereoscopic image reproduction method is called parallax barrier technique. This method is based on the idea of showing different images on a display through a blocking barrier that has only one vertical slit open at a time. Each open slit has certain image shown through it. This technique, however, reduces display resolution and results in a low light display since the parallax barrier blocks most of the light.

4. Paragraph 24:

[0024] In {1950"s} 1950's research on Integral Photography by Roger de Montebello lead to new inventions that helped eliminate the pseudoscopic effect by geometrically reorienting elemental images. However some problems still remained. Among these problems are the limit of the image depth that could be provided without blurring, the relatively expensive process of making lens arrays, the problem of lens aberrations, the reflection of light from the lens array that causes the observer to focus his or her eyes on the plane of the display instead of the virtual image behind the screen and thus making it difficult to observe the stereoscopic effect.

5. Paragraph 32:

[0032] In accordance with the objects of the invention, a stereoscopic display apparatus broadly {comprises of} comprising a backlighting means for projecting light, a spatial light modulator for modulating light emanated by the backlighting means, lens array {comprising of} comprising a plurality of lenses and an optional aperture screen for blocking unwanted light. The aperture screen is used with arrays of converging lenses as a device for selecting only those rays

from the backlighting means that have a predetermined direction before entering the spatial light modulator. Rays having said predetermined direction are modulated by the spatial light modulator and then refracted by lenses of the lens array. Individual lenses translate spatial modulation of the spatial light modulator into directional modulation by refracting the incoming rays. Also each lens collects all rays with said predetermined direction at focal point. Individual apertures are placed at the focal points of lenses and block any unwanted light.

6. Paragraph 44:

[0044] FIG. 5 is a diagrammatic section through {a} the second embodiment of the collimated light source used in the preferred embodiment of the invention.

7. Paragraph 45:

[0045] FIG. 6 is a diagrammatic section through {a} the third embodiment of a collimated light source used in the preferred embodiment of the invention.

8. Paragraph 47:

[0047] FIG. 8 is a diagrammatic section through {a} the second embodiment of the autostereoscopic display apparatus where the back lighting means is a point light source.

9. Paragraph 48:

[0048] FIG. 9 is a diagrammatic section through {a} the third embodiment of the autostereoscopic display apparatus where the back lighting means is an array of point light sources.

10. No marked up copy is necessary for this amendment, since new paragraphs were added.

11. Original paragraph 49, now paragraph 53:

[0053] Referring to FIG. 1, the preferred embodiment of an autostereoscopic display apparatus {comprises of} comprising a spatial light modulator 1 that is illuminated with collimated light 4, lens array 2 and the aperture screen 3. This apparatus is used to recreate a light field that would be a good approximation to the light field from a three-dimensional scene. The modulating photogram is displayed by means of the spatial light modulator. An opaque box is preferably fitted around the rear and the sides of the autostereoscopic display apparatus to exclude extraneous light.

12. Original paragraph 50, now paragraph 54:

[0054] The term "spatial light modulator" as defined herein means a devise whose optical transparency and color at different points can be controlled. The most primitive example of a spatial light modulator is a slide or a picture printed on a {peace} piece of plain transparent material. Another example of a spatial light modulator is a liquid crystal display (LCD).

13. Original paragraph 51, now paragraph 55:

[0055] As shown, there is provided a lens-array 2, preferably of a transparent, uncolored plastic material formed as a closely packed network of small uniform elements. Each element should collect the incoming parallel light at a focal point in front of the lens-array. Elements could be conventional lenses, however since elements do not have to deal with the light incident from any direction other than orthogonal to the plane of the lens-array, they could be Fresnel or diffraction lenses. The packing of lenses is preferably hexagonal or honeycomb pattern, as shown on FIG. 1, but could be any other arrangement, such as square or triangular. The lens array can also be replaced with a lenticular screen comprising {of} a plurality of cylindrical lenses placed next to each other in the horizontal direction.

14. Original paragraph 53, now paragraph 57:

[0057] As shown on FIG. 2, each elemental image {30} 20 of the modulating photogram realized on the spatial light modulator depicts a portion of light field as seen through the window bounded by said elemental image from the point that is situated on the corresponding lens axis one focal distance away from the elemental image. Said focal distance is the focal distance of the corresponding lens of a lens array. The purpose of each elemental image is to reproduce light irradiance and wavelength for all directions within the display's field of view. However, each elemental image by itself does not reproduce the direction of the light. Lenses of the lens array placed next to the spatial light modulator reconstruct the light direction.

15. Original paragraph 55, now paragraph 59:

[0059] By way of additional explanation, reference is had to FIG. 3, which shows the setup used in a preferred embodiment of the invention. FIG. 3 and other figures are not drawn to scale and are provided purely for illustrative purposes for easier description of the invention. It is a principle of optics that the source of any ray can be found by reversing the direction of the ray and tracing it through the optics back to the source. As shown in {FIG. 2} FIG. 3 two eyes of an observer 10 and 11 are observing a static virtual object 30 through the plane of the aperture screen 3. Individual apertures are lettered A, B, C, ... I. Each aperture represents a unique point on the screen surface of an autostereoscopic display. Each said point or aperture emits light of different irradiance and color content for different directions. The eye 10 looking in the direction of point E sees the top 32 of the virtual image 30. As can be seen from the FIG. 3 the information about this virtual point,

16. Original paragraph 57, now paragraph 61:

[0061] Suppose the observer moves to a different location and looks at the autostereoscopic display with two eyes placed as 12 and 13 on the {FIG. 2} FIG. 3. The two eyes will observe different points from the aperture B. Specifically the eye 13 will see the top 32 of the virtual object 30, while the eye 12 will observer the bottom 31 of the same virtual object 30

17. Original paragraph 58, now paragraph 62:

[0062] As it can be seen from the {FIG. 2} FIG. 3 the eyes 10 and 11 observe different views. Therefore the binocular parallax depth perception cue is reproduced by the given autostereoscopic

display. Furthermore, as it is seen from {FIG. 2} FIG. 3 whenever the observer moves around, the static virtual image used in the diagram stays at the same location behind the screen. Thus the monocular movement parallax is exhibited by the presented display. On another hand, when the eyes 10 and 11 are focused on the same virtual point 32 then the viewing axis of the two eyes will {lye} lie along the lines connecting corresponding eye with the virtual point 32. Therefore, there is an angle between the two viewing axis of observer's eyes and the convergence depth cue is perceived. Similarly, a virtual point (not shown) that is a little closer than 32 to the observer's eyes 10 and 11 will appear out of focus when the eyes are focused on the point 32. Thus accommodation depth cue is exhibited by the presented autostereoscopic display.

18. Original paragraph 59, now paragraph 63:

[0063] FIG. 2 shows a large-scale view of part of the autostereoscopic display apparatus. It shows one lens 21, an aperture 22 and part of the spatial light modulator 20 that presumably displays one elemental image of a modulating photogram. There are four stages 25, 26, 27 and 28 that the light from the back lighting means travels through. Stage 25 is a stage where in the preferred embodiment of the invention the light 4 is collimated and no information is reconstructed. Light passes through the spatial light modulator and reaches the stage 26 where light color and intensity for the point in the center of the aperture 22 is reconstructed. Then the lens 21 refracts the light giving every ray the proper direction and the light reaches stage 27. At this stage the spatial modulation is translated into directional modulation for the point in the center of the aperture 22 and distribution of color and intensity for the said point is reconstructed. The aperture

22 in the aperture screen 3 blocks scattered, reflected and other unwanted light and passes only the light that contains information reconstructed about the virtual scene. When the light reaches the stage 28 all distribution of light for the point in the center of the aperture 22 has been reconstructed. An individual aperture 22 can be thought of as a point on a screen of the autostereoscopic display {6}.

19. Original paragraph 60, now paragraph 64:

[0064] The first important part of the invention is the realization that the spatial light modulator and the lens array should only deal with light rays with predetermined direction at all points on the surface of the spatial light modulator. Preferably the backlighting means should emit a non-diffused light, for instance collimated light. This fact together with close arrangement of the modulating photogram and the lens array eliminates the problem of lens aberration and blurring typical to the conventional Integral Photography. In the conventional Integral Photography the image is placed somewhere close to the plane formed by focal points of the lens-array. The method relies on the approximation that parallel light incident on an arbitrary lens at any angle would focus on the focal plane. In reality the focal plane does not exist {doe} <u>due</u> to lens aberrations that are commonly present in lenses with short focal distance. Hence there arises a blurring problem. When parallel light is used to backlit the modulating photogram the blurring problem is no longer present, since all that is required of any lens is to focus parallel light. Lenses in the present invention do not have to focus light incident from any direction other than the predetermined direction of the back lighting beam. In the preferred embodiment of the invention this direction is

orthogonal to the plane of the lens array. This leads to another important part of the present invention: relieved requirements on functionality of lens array. Namely, the only requirement is the ability to focus light that has a predetermined direction. This allows usage of Fresnel lenses or diffraction lenses in the lens-array. These lenses have many advantages compared to conventional lenses. They are usually cheaper to produce and hence may reduce the total cost of the autostereoscopic display production. Fresnel lenses are thinner and therefore cause less chromatiacal aberrations. Another important advantage of Fresnel and diffraction lenses is that it is possible to create lenses with a very short focal distance. The shorter the focal distance is the {large} larger the autostereoscopic display's field of view becomes. Conventional lenses with a very short focal distance have large aberrations and thus can not be used effectively. Fresnel lens array, however, can have a very short focal distance without introducing any substantial aberrations in focusing incident light that has a predetermined direction.

20. Original paragraph 62, now paragraph 66:

[0066] The method for showing photograms as described in de Montebello's method exhibits strong reflection from the lens-array. This problem makes it difficult for an observer to focus on the virtual image behind the screen because the reflected light intensity could mask the light that forms the virtual image. An opaque aperture screen introduced in this invention diminishes this problem to the point where it is no longer relevant. Given that apertures are sufficiently small the light that goes through them is only the light that was recorded on the modulating photogram, there is practically no reflection light. This makes it easy for a person in front of the screen to observe a

virtual scene. It is preferred that the aperture screen is made out of opaque material such as a thin plastic or metallic panel of a black matte color. Apertures should be made as small as possible. However, {apertures"} apertures' shape and size should ensure that blocking of the light to be focused is negligible. In the preferred embodiment of the invention apertures should not block any light that was emanated by the collimated light source and then refracted by lenses of a lens array. An example depicted on FIG. 7 illustrates calculations of a cylindrical aperture's diameter. As can be seen there is provided a lens 21 that has field of view 70 equal to 45 degrees and the width of the aperture screen panel 3 is 1mm. In order for the aperture not to block any light coming out of the lens the minimum diameter of the aperture 22 should be 1mm.

21. Original paragraph 70, now paragraph 74:

[0074] One of the important advantages of the invention over prior art is the fact that the autostereoscopic display apparatus is not time multiplexed. Those skilled in the art are familiar with an approach where back lighting beam changes direction with time and passes through a spatial time modulator. Thus light intensity and color are shown for each different direction at different times. Such approach has been called time multiplexed. However, said method requires spatial light modulator to function at a very high frequency since there can be a very large number of directions for which the light has to be modulated. In addition, in order to avoid flickering, the full modulation cycle through all directions has to happen around 24 times a second. This means that such apparatus reproducing 100 different directions has to have a spatial light modulator that

works at a frequency around {2.5kHz} 2.5 kHz for reproduction of a static stereoscopic picture. Such devices are very expensive to produce if at all possible.

22. Original paragraph 71, now paragraph 75:

[0075] The present invention introduces a device that is not time multiplexed. No changes in the system are required to show a single static three-dimensional image. To produce motion autostereoscopic picture the spatial light modulator has to modulate light differently at the rate at least 24 times a second. This means that the spatial light modulator has to work at a normal frequency of {24-80Hz} 24-80 Hz. Such frequency eliminates any flickering. A readily available liquid crystal display can be used in the system.

23. No marked up copy is necessary for this amendment, since new paragraphs were added.

24. Abstract of the disclosure:

An autostereoscopic display apparatus broadly comprises {of} a backlighting means for projecting light, a spatial light modulator for modulating light emanated by the backlighting means, lens array comprising {of} a plurality of lenses and an optional aperture screen for blocking unwanted light and for minimizing reflections from the external lighting. Said apparatus is used to reproduce directional distribution of light from a computer generated or a photographically captured three-dimensional scene. It is preferred that a collimated light source is used as the backlighting means. The aperture screen is used to improve the quality of the

autostereoscopic image when the backlighting means exhibit some diffuse properties. For instance, the aperture screen can be used as a device to select only those rays from the backlighting means that are {have a predetermined direction. For instance rays} orthogonal to the plane of the spatial light modulator. {If the backlighting means are such that the emitted light has a predetermined direction then the aperture screen may be avoided. The spatial light modulator modulates light assuming that it only comprises of rays that have a predetermined direction. Each lens of the lens array translates spatially modulated light into directionally modulated light so that the directional distribution of light at each point of the array approximates the light emanating from the three-dimensional scenery to be reproduced. Preferably each lens is a converging lens so that it collects the light near its focal point. Individual apertures of the aperture screen coincide with focal spots of the lens array and select only the light that focused at those focal spots. Each aperture emits directionally modulated light where light intensity at every direction can be controlled by the spatial light modulator. Plurality of apertures comprises the three-dimensional picture visible on the autostereoscopic display.}

25. No marked up copy is necessary for this amendment, since the entire set of pending claims has been replaced.